



Subsurface Exploration Technologies and Strategies for Europa

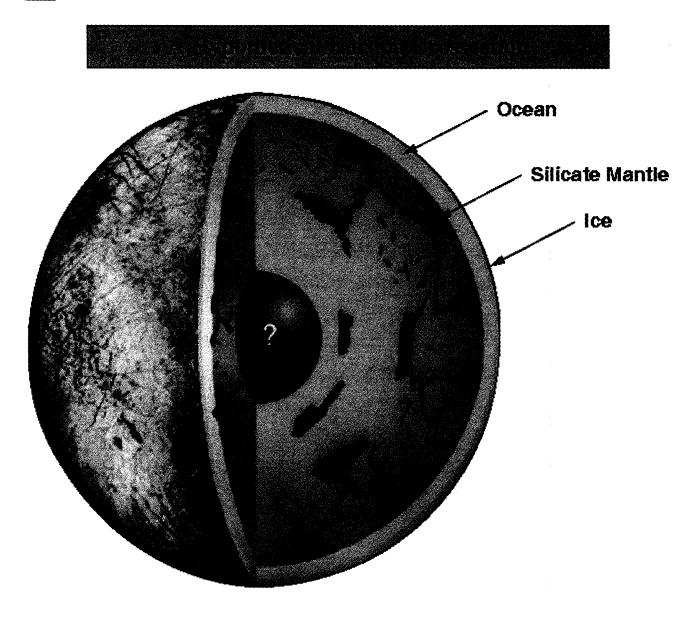
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JPL

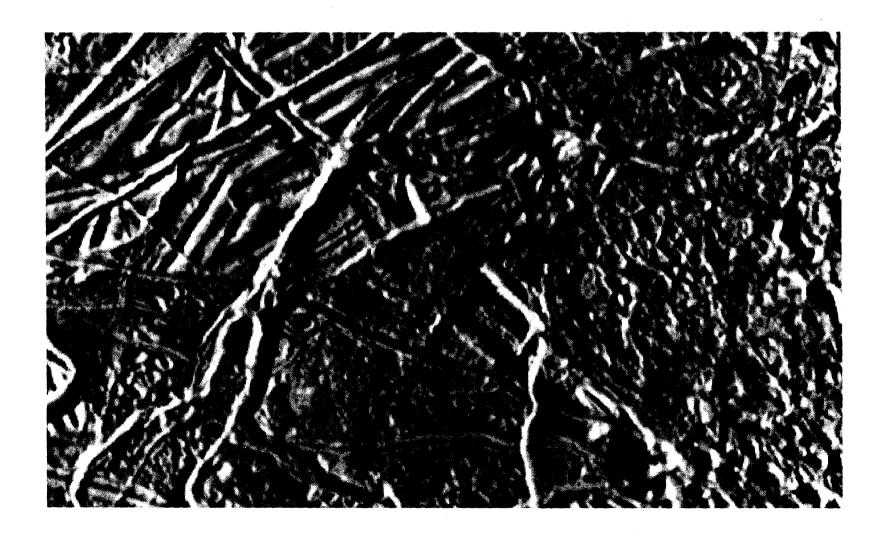




JPL











It Is

(Probably):

Old

As Old As Europa Itself: 4 Byrs

Deep--

Gravity Data Indicate an Ocean 75km to 200 km deep

Ice Covered--

Various Considerations Argue for Ice 5-30 km Thick

Saline---

Magnetic Data Indicate Ionic Salts
Surface Spectra Indicate Salts Similar to Earth's Oceans

• Unpleasant, Expensive, Challenging--

Hot with Radiation; Thermally Cold (70-100K); Dim Distant; in Jupiter's Gravity Well Pristine

Compelling





This is a List We Know How to Write:

Vehicles for Mobility in Ice and Water

Methods for Regional/Global Surveys (Sounding Radar)

Power/Communications systems

Miniature Scientific Instruments

Planetary Protection

Autonomy for Science and Operations

We Have Started to Addess that List



Europa Subsurface Mission





Critical Technology

- Subsurface Access
- In situ instrumentation
- Contamination control

Other Important Technology

- Subsurface navigation
- Communications
- Power sources

Science Objectives

- Search for evidence of life
- Determine the physical and chemical characteristics of ice
- Determine chemical, physical and biological properties of the ocean

Mission Description

- Landing site: Within selected region (thin ice crust or non-deforming ice)
- Subsurface : Descend 20-30km to the ice/water interface
- Telecon/Navigation: In-Ice transceivers and Lander telecom
- Cost: TBD
- Option: Profile Study of Water, Sediments

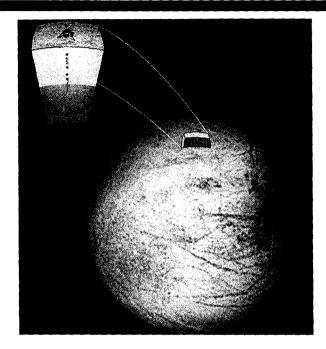
• Measurement Strategy

- Determine composition and temperature as the probe descends through the ice
- Image features within the ice and ocean
- Establish ocean observatory at base of ice



Europa Subsurface Mission





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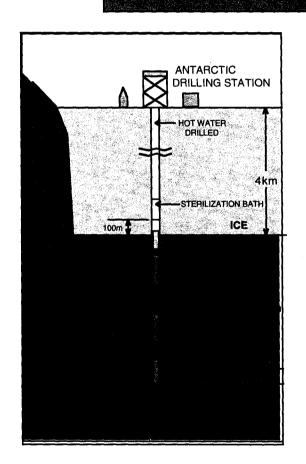
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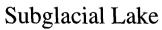
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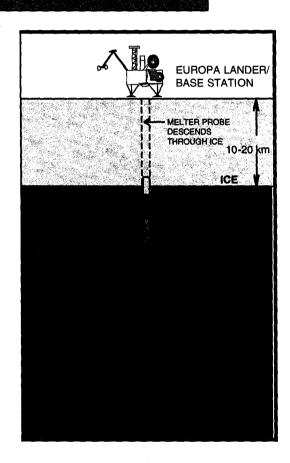
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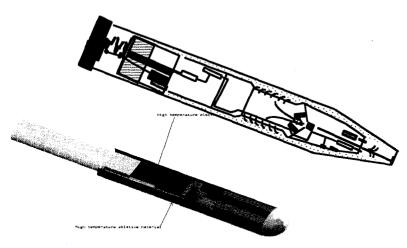




Europa

90 km

JPLCETDP ACTIVE THERMAL PROBES FOR ICE SITES



Two Point Designs for Thermal Probes, vehicles for movement in ice

Task Manager

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Team

JPL: Scott Anderson, Frank Carsey, Emily Eelkema, Winston Fang, Jason Feldman, Gindi French, Jeff Hall, Dan Helmik, Corey Harmon, Partha Shakkotai, Jan Tarsala, Brian Wilcox, Wayne Zimmerman

CIT: Hermann Engelhardt, Robin Bosley

ASU: Jack Farmer

Description:

Thermal Ice Probe technology development for advanced in-situ capability and mobility. **Objectives:**

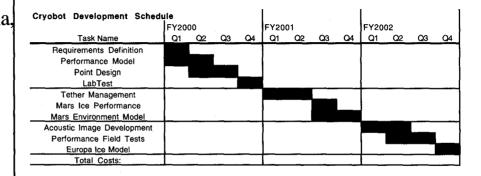
FY '01: Testing mobility in ice/sediment environments

FY '02: Tethered field operation and acoustic development

FY '03: Mobility in ice/vacuum and ice transceiver development

FY01 Level 1 Goals:

- •Demonstrate mobility in ice/sediment mixture
- •Tether development







Technology and its Relevance to Missions

The Active Thermal Probe technology has wide applicability to a variety of mission scenarios. By gaining access to the icy subsurface environment, the technology fosters in-situ science exploration. The Active Thermal Probe can take instrument suites to depth through changing stratification. Instruments can include cameras, spectrometers, and insitu sampling instruments.

Icy Body Environments

- •Comets (100m depth)
 - Subsurface Access
 - •In-Situ sampling

Liquid Environments

- •Europa (5-7km depth)
 - •Ocean and In-Situ Exploration
- •Titan (3-5km depth)
 - Prebiotic Exploration

Polar Cap Environments

- •Earth (2-4km depth)
 - •Arctic and Antarctic climatic circulation
 - •Antarctic geophysics and ice dynamics
 - •Subglacial Lake Exploration
- •Mars (50m 200m depth)
 - •Subsurface Polar Cap Exploration
 - •Climate history science
 - Exobiology science



Comparison of Cryobot w. Historical Penetrators

Research Org Penetrato Expedition Glaciology International (Philberth, 62)	r Type Physical Des Passive heater Melt rate=	Length= 2.5 and 2.9m Dia= 10.8cm Power= 4kw	Performance Greenland ice-pack - Heater burnout	Depth= 218m/1km Observations: - Short circuit
Army Cold Regions Research and Engineering Laboratory (CRREL) (Aamot, 64)	Pendulum stabl. Passive heater	Length= 2.5m Dia= 10cm Power= 3-4kw	Greenland and Antarctic ice-packs - Cable fail.	Depth= 6-260m Observations: - Heater burnout - Electronic fail.
Univ of Nebraska (PICO) (Hansen, 84, 93, 94)	Pendulum stabl. Passive heaters in nose/shell w. ability to switch heaters on/off	Length= 3.45m Dia= 12.7cm Power= 5.4kw Melt rate= 2-4m/hr	Greenland ice-pack	Depth= 120m Observations: - Heater burnout - Coax cable fail.
Acad of Mining and Drilling Russian Antarctic Expedition	Elec/mech ice corer	Length= 2m Dia= 8-10cm Power= 3-5kw Drill rate= 1-2m/hr	Antarctic ice-pack	Depth~ 3km Observations: - System robust - Contam. anti- freeze liquid rqrd (e.g., diesel fuel) - Signif GSE rqrd
California Inst of Tech (Englehardt, 90-00)	Hot water drill w. water recirculated back to surface to allow reheating	Length< 1m d Dia= 14cm Power= 1-2Mw Melt rate= 3-5m/hr	Antarctic ice-pack	Depth~ 1km Observations: - System robust - Large energy rqrd - Signif GSE rqrd
Jet Propulsion Lab (Cryobot team, current)	Passive/active jet Heaters in nose/ shell w. ability to switch heaters Autonomous cntrl	Length= 1.25m Dia= 12cm Power= 1kw Melt rate= .5-1m/hr	Antarctic ice-pack Mars N. polar cap Europa ice-pack	



Active Thermal Probe



Technical Accomplishment:

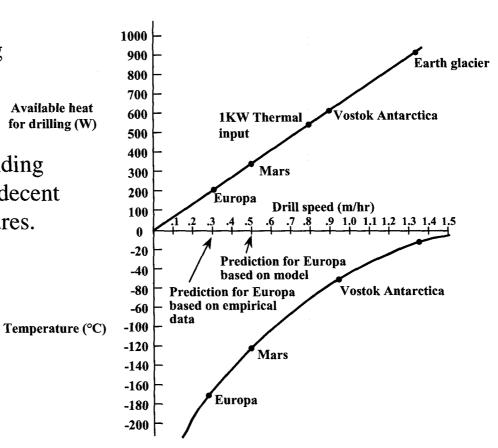
Melting performance modeling using water jetting as a vortex drill.

> Available heat for drilling (W)

Knowledge gathered helps understanding relationships between power inputs, decent rates, and ice environment temperatures.

Significance to NASA:

- •Mobility through subsurface ice environments is possible.
- •New access for instrumentation tools for scientific community.
- •Subsurface exploration of icy planetary environments is feasible.



Drill Speed vs Heat and Temperature

Task Manager:Lloyd French





CRYOBOT DRILLING PARAMETERS PHASE 1

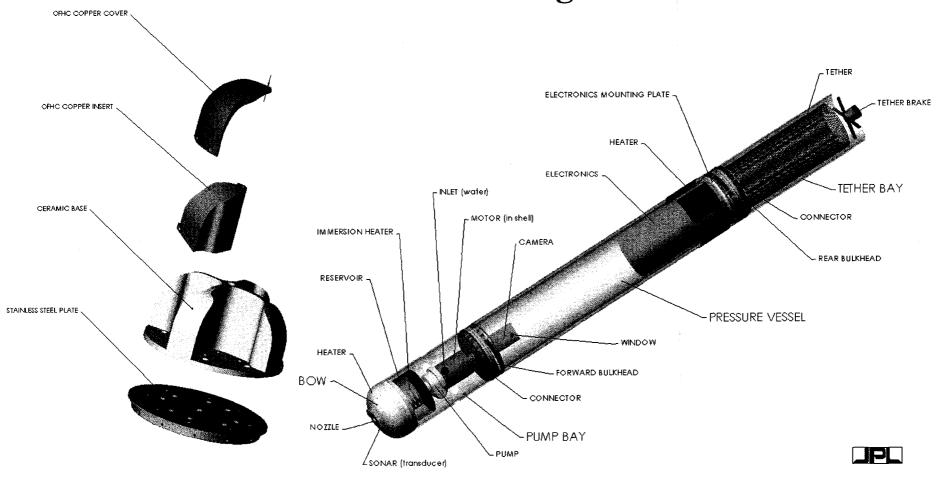
(version 6 MARCH 2000)

•	MELTING POWER	0.6 - 0.8 kW
•	DRILLING NOZZLE DIA	1.0 - 1.25 mm
•	WATER TEMPERATURE	20 - 25°C
	AT NOZZLE	
•	WATER TEMPERATURE	5 - 6°C
•	RETURN WATER PRESSURE	1 - 2 bar
•	WATER JET VELOCITY	10 - 20 m/s
•	WATER FLOW RATE	1 - 1.5 l/min
•	DRILLING SPEED	0.3 - 1.0 m/h
•	DRILLING EFFICIENCY	80 - 90 %
•	ICE TEMPERATURE	-10°C
•	CRYOBOT OUTER DIA.	10 - 12 cm
•	CRYOBOT LENGTH	1 - 2 m





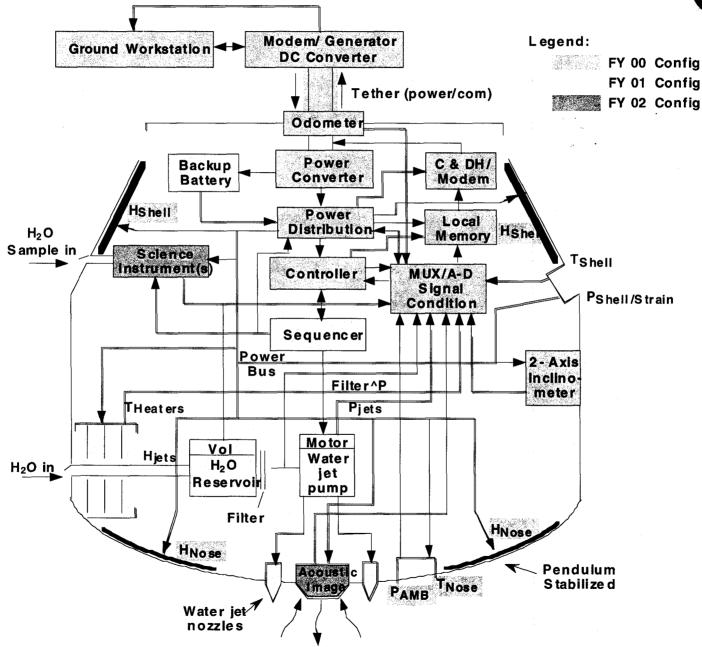
Baseline Design





Cryobot Functional Control Block Diagram







Active Thermal Probe



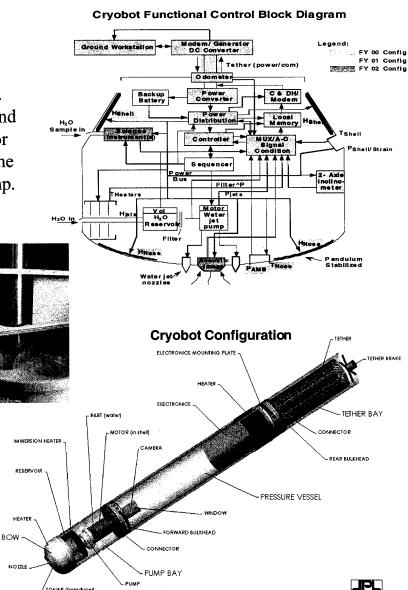
Technical Accomplishment: The Cryobot design team completed its mid-year design review on April 25, 2000. This review provided brassboard level designs for the mechanical aspects of the probe, control electronics, instrument interfaces, and software control. Also presented were supporting empirical test results on both active and passive melting tests which clearly showed that the original models for melt rates/ efficiencies were correct. These results were essential to the sizing/selection of the electronic components, heaters, and motor/pump. The current probe design is now sized (both in terms of power and geometry) close to the proposed flight design. This is a significant achievement.

Technology: Thermal fluid modeling. High efficiency active and passive melting. Tether bundle packaging.

Significance to NASA:

- Current empirical tests clearly show that it is possible to achieve .5 m/hr melt rates in cold ice with 1Kw thermal--this equates exactly to projected energy requirements for a similar cryobot application to Mars Polar regions or Europa;
- The current Cryobot prototype design will use off-the-shelf commercial electronic/mechanical components--this design strongly suggests that it is feasible to meet science/functionality/control requirements while maintaining a flight-like configuration (~1m in length, 12cm dia);

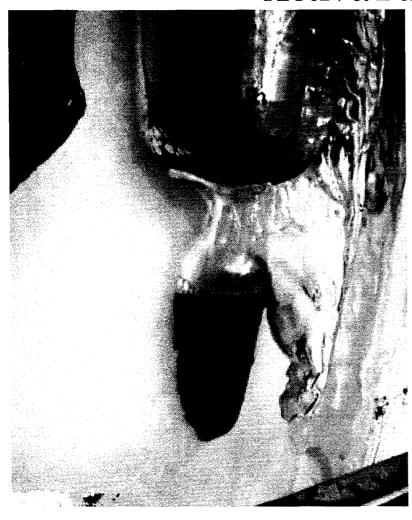
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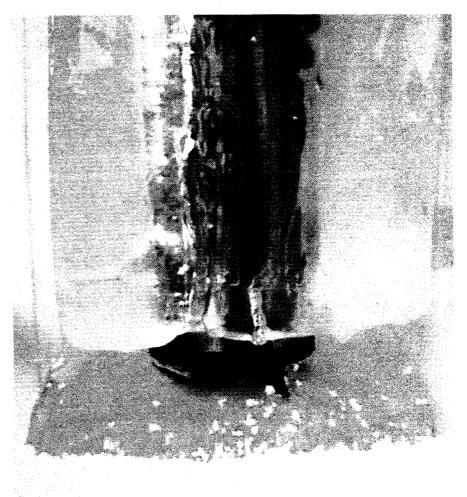






Active/Passive Tests







Active Thermal Probe



Technical Accomplishment:

Mobility through 5m of ice. Utilizing Active/Passive melting systems. Added demonstrated capability of steering during descent.

Total time:

11.3 hrs

Ave Power:

417.7 W

Ave Descent Rate: 43.4 cm/hr

Significance to NASA:

•Mobility through subsurface ice environments is possible.

•New access for instrumentation tools for scientific community.

•Subsurface exploration of icy planetary environments is feasible.



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Current Related Program Activities

- In-Situ Instrumentation Frank Carsey/A. Lonne Lane; JPL
 - Antarctic Ice Borehole Camera
 - Code Y; Long-Term climate change science
 - Incorporating instrument and tether technology into cryobot.
 - Hydro Thermal Vent Probe
 - Code S; Instrumentation Development
 - Incorporating instrument packaging and field operations experience.
- Planetary Protection Roger Kern; JPL
- Cryofacility Development Lloyd French/Jacklyn Green; JPL
- Science project utilization of Cryobot (first proposals in '01)
- Extraterrestrial Materials Simulation Laboratory Jacklyn Green; JPL
 - Deep-Space ET Program
 - Development of ice/dust mixtures with varying densities.



Subsurface Access Technology Development





Critical Technology

- Science Assessment
- In situ instrumentation

Other Important Technology

- Data Handling
- Contamination control

 Extended cryobot capabilities
- •(Sample return, coring, etc)

• Science Objectives

- Profile physical, chemical and isotopic properties of ice and inclusions
- Characterize biology of Ice and Bed

Mission Description

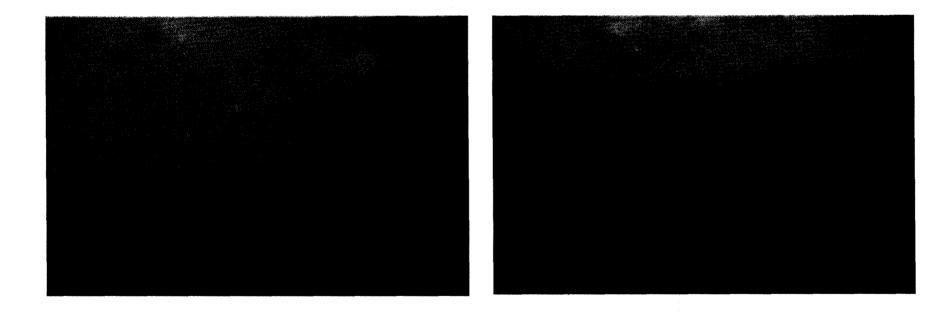
- List and evaluate science objectives and requirements
- Develop and test instruments
- Develop field project concepts
- Cost: TBD per year

Measurement Strategy

- Determine composition and isotopic abundance within ice/ocean environment
- Optical investigations of subsurface features
- Evaluate new micro-instrumentation
- Assess sample return: water, ice, sediments

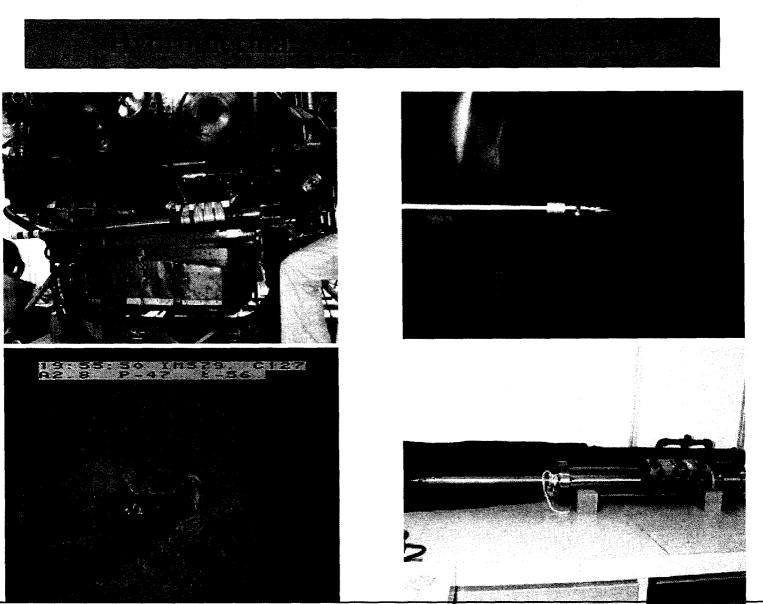
















Major Milestones for FY 01 and Beyond

• FY 01: Mobility in ice/sediment and tether development

• FY 02: Tethered field operation and acoustic development

• FY 03: Mobility in ice/vacuum and ice transceiver development

• FY 04: Consequences of Contamination control

• FY 05: Subglacial lake field operation

• FY 06: Subsurface sample return development